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(58) Field of search
F4U

(54) Thermal storage device

(57) A thermal storage device comprises a flexible enclosure (2,3) formed of a metal foil (4) sandwiched between two layers of plastics material (5,6) and containing a phase-change material capable of emitting latent heat on phase-change, and an electrical heating element (8) comprising a flexible conductive member (9) sandwiched between two layers (10) of flexible, non-conductive plastics material, the heating element being in thermal contact with the phase-change material and connectible to a source of electrical energy.

FIG. 2.

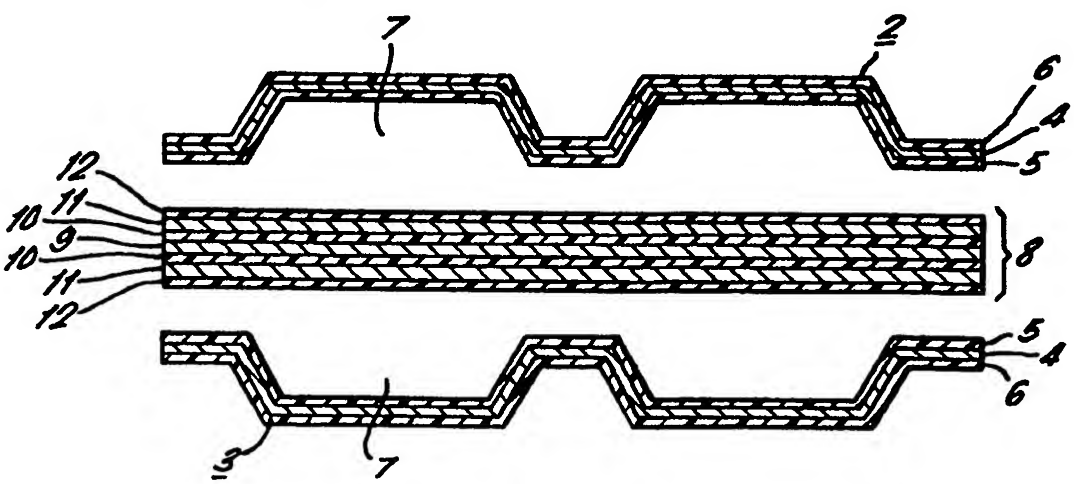

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FIG. 1.

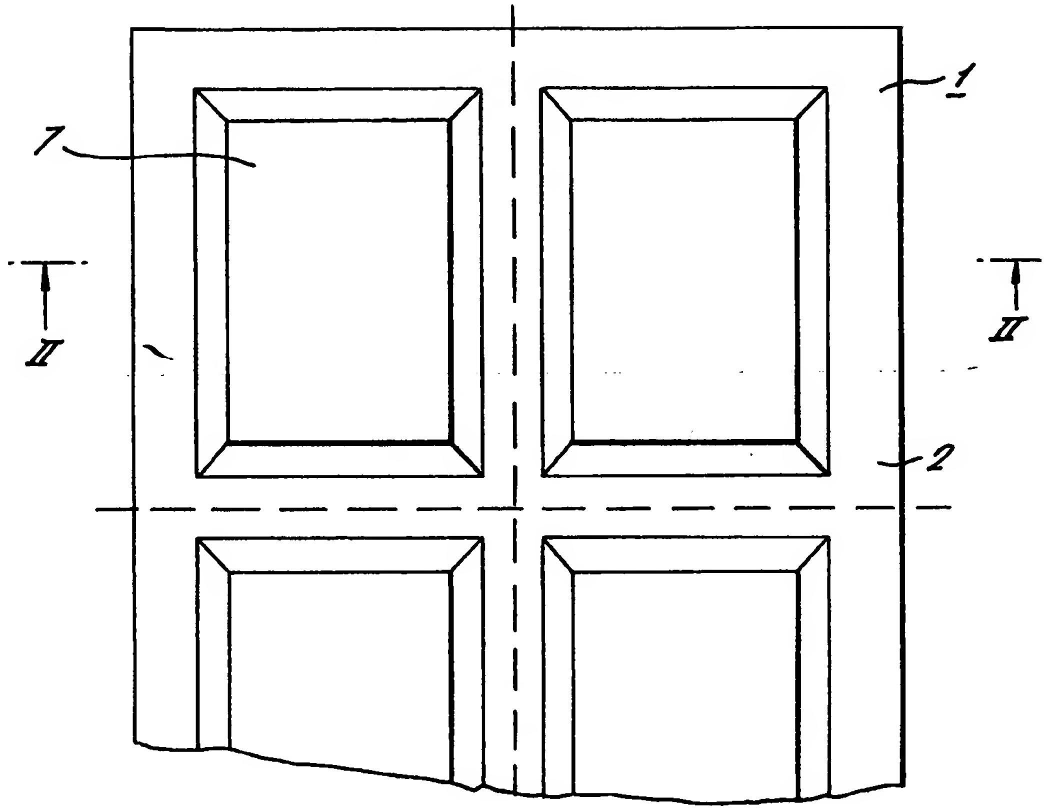

FIG. 2.

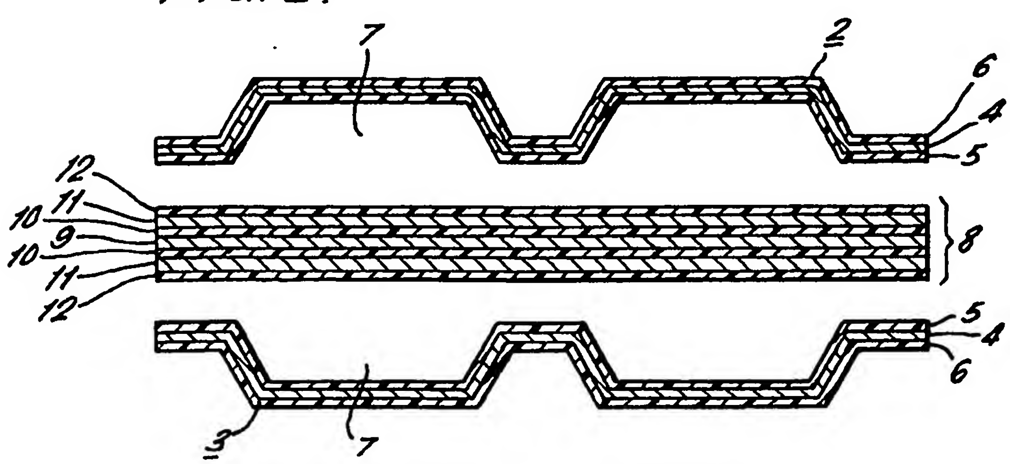

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FIG. 3.

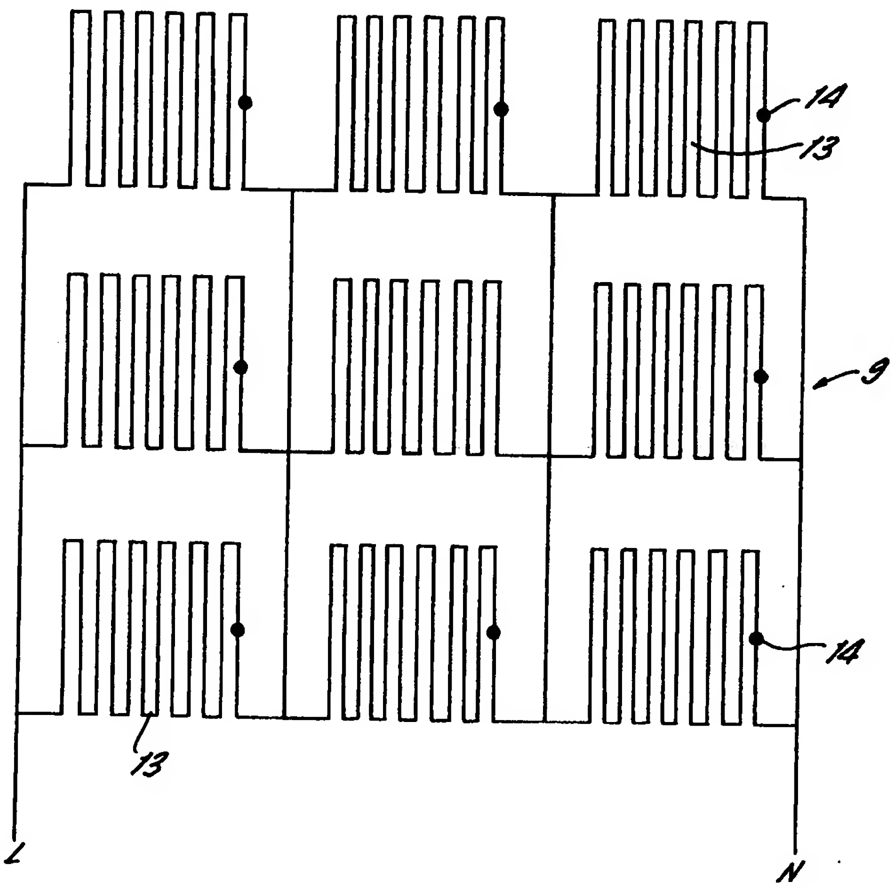


FIG. 4.

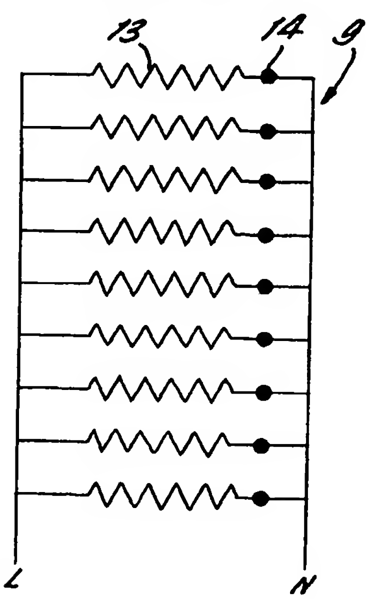


FIG. 5.

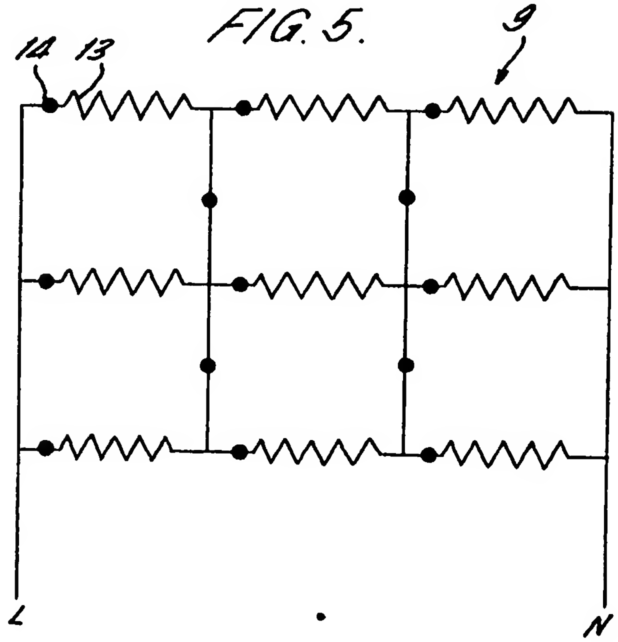


FIG. 6.

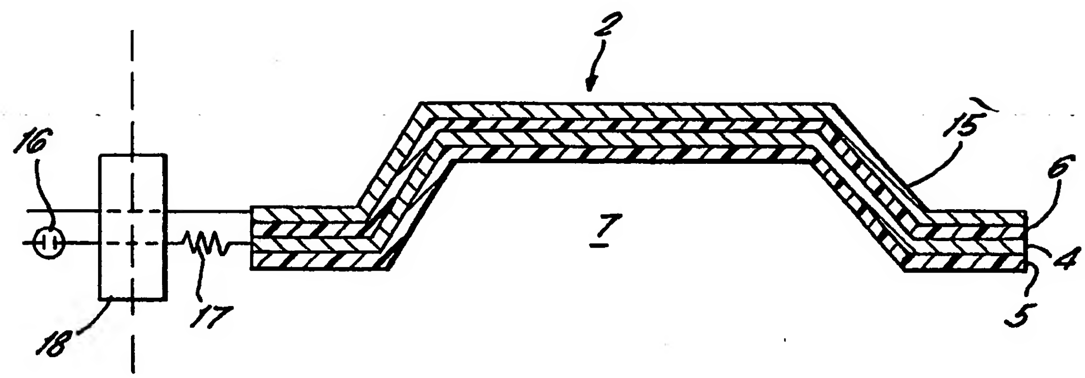
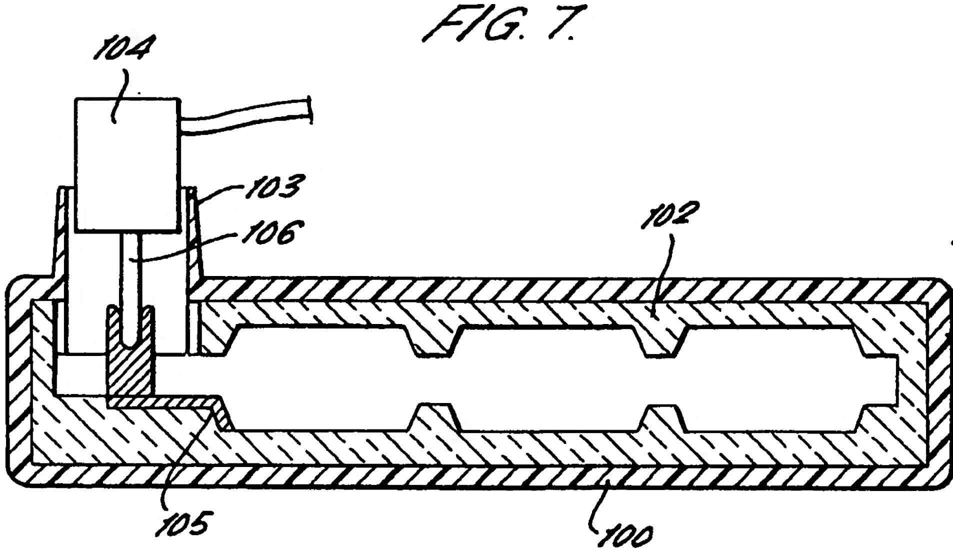


FIG. 7.



SPECIFICATION

Thermal storage device

This invention relates to a thermal storage device.

Materials are known which on changing phase emit latent heat, and such materials are particularly suitable for use in certain types of thermal storage device since they can provide a high level of heat storage per unit volume of the device together with a substantially constant heat output from the device for a relatively long time, at a substantially constant temperature.

A number of such phase-change materials are known, a particular example being a material marketed by Dow Chemical Company as Dow 57, this being a eutectic of magnesium chloride and magnesium nitrate hydrates, which after heating to change the material from the solid phase to the liquid phase will on being allowed to cool emit not only sensible heat but also latent heat deriving from the return of the material from the liquid phase to the solid phase.

According to this invention there is provided a thermal storage device comprising a flexible enclosure containing a phase-change material capable of emitting latent heat on phase-change, and an electrical heating element in thermal contact with said phase-change material and connectible to a source of electrical energy.

The device of this invention is particularly suitable for use as a substitute for a conventional hot water bottle, or as a body heating pad for use for medical or comfort purposes. The device can be heated by connection to a source of electrical energy, and thereafter disconnected from the source and moved to its place of use. The flexible nature of the device enables it to be applied to conform to, for example, a part of a human body to be warmed by the device.

This invention will now be described by way of example with reference to the drawings, in which:–

Figure 1 is a diagrammatic plan view of part of a thermal storage device embodying the invention;

Figure 2 is a diagrammatic exploded sectional view on the line II–II in Fig. 1;

Figure 3 is a diagrammatic representation of an electrical heating element suitable for use in the device of Fig. 1 and 2;

Figures 4 and *5* are diagrammatic representations of two forms of heating element suitable for use in the device of Figs. 1 and 2;

Figure 6 illustrates a modification of the device of Figs. 1 and 2 to include a warning device operative to indicate leakage of material in the device; and

Figure 7 illustrates a container in which the device of Figs. 1 and 2 can be initially heated and stored.

The thermal storage device shown in Figs. 1 and 2 comprises a flexible enclosure 1 formed by two wall members 2 and 3 each comprising an aluminium foil layer 4 sandwiched between an inner layer 5 of polypropylene and an outer layer 6 of polyester. Each wall member 2 or 3 defines a matrix arrangement of pockets 7 with the pockets in the two members 2 and 3 being in register, as shown in Fig. 2.

Arranged between the two wall members 2 and 3 is an electrical heating element structure 8 comprising a flexible conductive member 9 sandwiched between two layers 10 of flexible, non-conductive plastics material. The conductive member 9 constitutes the actual heating element and is connectible to a source of electrical energy by means of a plug and socket connection (not shown) such that in use the member 9 serves to heat the pockets 7 defined by the wall members 2 and 3. The member 9 provides a power output of about 5000 to 8000 W/m².

The layers 10 of the heating element structure 8 are each covered by a layer 11 of aluminium foil which is in turn covered by a layer 12 of plastics material. The aluminium foil layers 11 assist in achieving an even distribution of the heat dervied from the heating element layer 9, throughout the device when being heated from the source of electrical energy, and during the subsequent emission of heat from the device.

In the assembled state of the device the inner layers 5 of plastics material of the wall members 2 and 3 are bonded as by welding to the outer plastics material layers 12 of the heating element structure 8 around the periphery of each of the pockets 7, such that each of the pockets 7 becomes a closed space.

Prior to bonding the pockets 7 are filled with a phase-change material as discussed in the introduction, the material thus being in close thermal contact with the heating element conductive member 9.

For use of the device described above the heating element 9 is connected to a source of electrical energy and the phase-change material in the pockets 7 is heated to the required temperature, during which the material changes phase, for example from the solid phase to the liquid phase. The device is then disconnected from the source and moved to its place of use where it cools down while heating, for example, a part of a human body, the heat emitted by the device deriving not only from the sensible heat stored therein, but also from the latent heat given out as the phase-change material changes phase again, for example returning from the liquid phase to the solid phase.

The device has the advantage that it is flexible when the phase-change material is in

a non-solid phase, and being flexible at least about the axes extending through the device between the rows and columns of pockets 7 when the phase-change material is in a solid phase.

Although in the device described above the heating element structure 8 is sandwiched between two enclosure wall members 2 and 3 each providing pockets 7 for the phase-change material, it will be appreciated that one of the wall members 2 and 3 can be omitted, whereby the heating element structure 8 will form one, normally planar, wall of enclosure 1.

The choice of different plastics material for the inner and outer layers 5 and 6 of the wall members 2 and 3 enables the inner layer 5 to be of a material compatible with the phase-change material in contact therewith, while the outer layer 6 can be of a relatively high strength material. The interposed metal foil layer 4 serves to provide an impermeable layer to ensure containment of the phase-change material while also giving resistance to puncturing of the enclosure 1 either from outside or by needle crystals which may be formed in the enclosed phase-change material. It will be appreciated that the wall members 2 and 3 can otherwise be made of other suitable materials; for example rubber, having the necessary containment and strength properties.

As shown in Fig. 3, the heating element conductive member 9 can comprise a plurality of inter-connected sub-elements 13 respectively associated with the pockets 7, or opposed pairs of pockets on opposite sides of the heating element structure 8.

Each sub-element 13 can include a temperature sensitive member 14, such as a thermistor, which can be, for example, embedded in the adjacent plastics material layer, and which is operative in use of the device to reduce the electric current flowing in that sub-element 13 on the occurence of local overheating at the pocket or pockets 7 heated by that sub-element 13, whereby further overheating is prevented.

The sub-elements 13 of the heating element conductive member 9 can be interconnected in a number of different ways, and Figs. 4 and 5 show two of the possibilities.

Referring now to Fig. 6, the or each enclosure wall member 2 or 3 can include a second outer layer 15 of metal, for example aluminium, foil electrically insulated from the other inner foil layer 4. If required the outer foil layer 15 can be covered with a further layer of plastics material (not shown).

A warning device, for example a neon lamp 16 is connected, possibly together with a current-limiting resistor 17, in a circuit including the foil layers 4 and 15 such that the warning device 16 will be operated in the event that an electrical connection is established between the foil layers 4 and 15, for example in the event that the enclosure 1 becomes punctured and the phase-change material leaks from a pocket of pockets 7. The warning device, being connected thereto when required by a plug and socket connection 18.

Referring now to Fig. 7, this shows a container 100 preferably but not necessarily of electrically and thermally insulating material in which a thermal storage device as described above can be stored, heated and maintained in a heated condition, prior to use as a portable thermal store. The container 100 comprises a rigid of flexible outer wall 101 and an interior insulating lining 102 shaped to receive the thermal storage device. As a modification the lining 102 can be omitted, and the space between the container 100 and the thermal storage device therein filled with a heat conducting liquid, or left empty with the container 100 serving simply as a protective cover. The container 100 has a socket arrangement 103 adapted to receive a plug 104 by which a device in the container is supplied with electrical heating energy.

The lining 102 of the container 101 includes a heat conductive pad 105 which contacts a device when in the container 100, and which is also contacted by a sensing probe 106 carried by the plug 104.

The probe 106 operates to sense the temperature of a device being heated in the container 100, by way of the pad 105, and to control the energy supply to the device to maintain the device at the required temperature.

The probe 106 can be part of a bimetal device acting directly on a connection in the plug 104, or otherwise the probe 106 can include a temperature sensitive element such as a thermistor, which element controls an electronic or electromagnetic switch in the energy supply circuit.

CLAIMS

1. A thermal storage device comprising a flexible enclosure containing a phase-change material capable of emitting latent heat on phase-change, and an electrical heating element in thermal contact with said phase-change material and connectible to a source of electrical energy.

2. A device as claimed in Claim 1, in which the heating element comprises a flexible conductive member sandwiched between two layers of flexible, non-conductive plastics material.

3. A device as claimed in Claim 2, in which the heating element further comprises a layer of metal foil on each of the layers of non-conductive plastics material, and a further layer of plastics material on each of the layers of metal foil.

4. A device as claimed in Claim 1, Claim

2 or Claim 3, in which the enclosure is formed of a metal foil sandwiched between two layers of plastics material.

5. A device as claimed in any preceding claim, in which the heating element constitutes at least one wall of the enclosure.

6. A device as claimed in any preceding claims, in which at least one wall of the enclosure defines a matrix arrangement of pockets each containing the phase-change material, the device being flexible about axes extending between the rows and columns of pockets.

7. A device as claimed in Claim 6, in which the heating element comprises a plurality of interconnected sub-elements respectively associated with said pockets.

8. A device as claimed in Claim 7, in which each sub-element of the heating element includes a temperature sensitive member operative in use of the device to reduce the electric current flowing in that sub-element on the occurence of local overheating at the pocket heated by that sub-element.

9. A device as claimed in Claim 4, or any one of Claims 5 to 8 as dependent upon Claim 4, in which the enclosure includes a second outer metal foil layer electrically isolated from the other inner metal foil layer, and including a warning device electrically connected to the two metal foil layers of the enclosure and operative to indicate establishment of an electrical connection between the two metal foil layers of the enclosure.

10. A device as claimed in Claim 9, in which the outer metal foil layer of the enclosure is covered by a further outer layer of plastics material.

11. A device as claimed in any preceding claim, including a temperature sensor operative in use of the device to effect disconnection of the heating element from the electrical energy source in the event of the temperature of the device exceeding a predetermined value.

12. A thermal storage device substantially as hereinbefore described with reference to the drawings.

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